Mars Atmospheric Science and Recent Mars Missions Workshop

San Lorenzo de El Escorial,
May 22-23, 2019

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

The Workshop will focus on the analyses of the Martian atmosphere, atmosphere-to-surface interactions and recent status of ongoing and future Martian missions.

Additionally, the topics of the Martian magnetic field, Martian geodesic studies related to the Phobos and Deimos eclipses will be analyzed. They offer an example to integrate the scientific and technological questions associated to the space instrumentation.

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Participants:

- Aguirre Maeso, Carlos (UAM Spain)
- Alday Parejo, Juan (Oxford UK)
- Barderas, Gonzalo (UCM Spain)
- Bermejo, Sandra (UPC Spain)
- De Castro, Antonio (UC3M Spain)
- Debei, Stefano (UNIPD Italy)
- Coccaro, Fabio (Alma-Sistemi Italy)
- Diaz Michelena, Marina (INTA Spain)
- Domínguez, Manuel (UPC Spain)
- Genzer, Maria (FMI Finland)
- Gómez, Felipe (CAB Spain)
- Harri, Ari-Matti (FMI Finland)
- Haukka, Harri (FMI Finland)
- Jiménez, Salvador (UPM Spain)
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- Martín, María Luisa (UVA Spain)
- Mateo-Martí, Eva (CAB Spain)
- Pascual Broncano, Pedro (UAM Spain)
- Quitián Hernández, Lara (UCM Spain)
- Rodríguez Manfredi, José Antonio (CAB)
- Romero, Pilar (UCM Spain)
- Russu, Andrés (UC3M Spain)
- Santos, Daniel (UCM Spain)
- Sastre Marugán, Mariano (UCM Spain)
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- Silvestro, Simone (INAF Italy)
- Usero, David (UCM Spain)
- Valero, Francisco (UCM Spain)
- Vázquez, Luis (UCM Spain)
- Vázquez-Poletti, José Luis (UCM Spain)
- Velasco, María Pilar (UPM Spain)

This meeting is also intended as an hommage to Profs. Francisco Valero and Luis Vázquez

Mars Atmospheric Science and Recent Mars Missions Workshop 22-23 May 2019, El Escorial, Madrid, Spain

AGENDA:

Tuesday 21st of May
Arrival Day

Wednesday 22nd of May
Workshop Day 1

09:00 Gathering to the Conference Room. **Opening** statement and Workshop LOC statement

Session 1

09:30 **Luis Vazquez:** The UCM Martian Studies Group: History and Achievements

10:00 **Ari-Matti Harri:** ExoMars 2020 mission objectives and payload

10:30 **Fernando Lopez Martinez / Andres Russu:** UC3M infrared sensors for Mars Atmospheric Science retrieval

11:00 **Coffee break**

Session 2

11:30 **José Antonio Rodríguez Manfredi:** MEDA, the instrument onboard Mars2020 to characterize the dust cycle and the environment near the surface

12:00 **M.P. Velasco:** Dynamic of the Martian atmospheric dust through fractional diffusion models

12:30 **Carlos Aguirre:** Dust Devils analysis by means of non-commutative tomography

13:00 **Manuel Dominguez:** Advanced numerical modeling of thermal sensors for Mars Exploration and working under smart controls

13:30 **Lunch break**

Session 3

15:00 **Daniel Santos-Muñoz:** Present and future of atmospheric numerical modelling

15:30 **Eva Mateo:** Planetary Atmosphere and Simulation Chamber

16:00 **Coffee break**

16:30 **Simone Silvestro:** Aeolian features on Mars

17:00 **Felipe Gomez:** Conditions for life to exits: determining environmental parameters on Mars

17:30 **Juan Alday:** Trace gas retrievals from ACS on board ExoMars TGO

18:00 **Wrap-up of the Day 1**

Thursday 23rd of May
Workshop Day 2

09:00 Gathering to the Conference Room

Session 4

09:30 **Salvador Jimenez:** Confinement of a charged particle in a quadrupolar magnetic field

10:00 **Gonzalo Barderas:** Geodetic Techniques for the Mars Exploration: positioning by means of Phobos eclipses and determining Mars figure parameters

10:30 **Fabio Coccaro:** In Situ Instrument for Mars luminescence dating application

11:00 **Coffee break**

Session 5

11:30 **Sandra Bermejo Broto:** Metamaterials for energy harvesting

12:00 **Alexander B Shvartsburg:** Dielectric resonant magnetic dipoles: paradoxes, prospects, the first experiments

12:30 **Jose Luis Vazquez-Poletti:** Computing Solutions for Mars Exploration: from the Cloud to Serverless

13:00 **Marina Diaz Michelena:** AMR instrument - Scientific objectives and previous measurements on terrestrial analogues

13:30 **Lunch break**

Session 6

15:00 **Mariano Sastre Marugan:** IN-TIME project: Overview and Definition of the Mars Radiation Environment

15:30 **Lara Quitián Hernández:** Aspects of the IN-TIME project: Martian Atmosphere

16:00 **Coffee break**

16:30 **Pilar Romero:** Minimum-thrust optimization in the mission design of aerostationary telecommunications orbiters

17:00 **Antonio de Castro:** Experimental characterization of the optical elements of the Dust Sensor (ExoMars '20)

17:30 **End of the day and wrap-up of the Workshop**

Friday 24th of May
Departure day

Abstracts
(by alphabetical order of the speaker):

Noncommutative tomography for dust-devils detection and analysis

C. Aguirre[1], R. Vilela-Mendes[2], L. Vázquez[3],

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The purpose of this work is the implementation of a new method of tomography-based signal analysis for the detection of events in the Martian and Earth atmosphere, such as dust devils. These are thought to play an important role in climate. Dust devils are convective vortices generated due to surface heating, thereby generating convective plumes of rising air with a pressure variation inside. Some of these vortices obtain horizontal wind speeds large enough for dust particles to be lifted off the surface and into the vortex and thus becoming dust devils.

For this study, the pressure data used are those obtained directly by NASA's Phoenix spacecraft, operational since May 25, 2008 through May 2010. The objective is to find pressure drops more or less pronounced, but well localized in time, with a very short duration. Special attention is devoted to non-commutative tomography, which provides very robust strictly positive probability densities in the presence of noise and also provides filtering and to separate signal components. Finally we propose a new technique called Adapted Tomography, where the data itself generates the transform space. Adapted tomography is based on using an operator with the shape of the event we want to extract, and this will be identified as the component of the signal we want.

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2. V. I. Manko and R. Vilela Mendes; Non-commutative time-frequency tomography, Physics Letters A 263 (1999) 53–59.
3. C. Aguirre and R. Vilela Mendes; Signal recognition and adapted filtering by non-commutative tomography, IET Signal Processing.
4. M.D. Ellehoj et al.; Convective vortices and dust devils at the phoenix mars mission landing site, J. Geophys. Res., 115, 2010.

Trace gas retrievals from ACS on board ExoMars TGO

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Trace gas retrievals from ACS on board ExoMars TGO The Atmospheric Chemistry Suite (ACS) on board ESA-Roscosmos ExoMars Trace Gas Orbiter started routine science operations in Mars 2018. ACS consists of three infrared spectrometers covering a total wavelength range from 0.7 to 17 µm, targeting the detection of trace gases, as well as the monitoring of the martian atmospheric state. The mid-infrared (MIR) channel is a high spectral resolution (resolving power of >=30,000) instrument dedicated to solar occultation measurements in the 2.2-4.4 µm range, conceived to accomplish the most sensitive measurements of trace gases in the Martian atmosphere. First results from MIR observations yield low upper limits of CH_4, as well as the profiling of more abundant species like CO_2 or H_2O. The MIR dataset also allows the characterization of the isotopic inventory of CO_2 and H_2O and its variability due to fractionation processes. Preliminary analyses also allow the retrieval of vertical profiles of CO, which will provide a further understanding of the Martian photochemistry.

Geodetic Techniques for the Mars Exploration: positioning by means of Phobos eclipses and determining Mars figure parameters

Gonzalo Barderas

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Universidad Complutense de Madrid

Abstract:

The main purpose of this work is to present two methods for Mars geodetic problems: First, we will show an alternative localization method for Mars exploration probes based on Phobos eclipses observations when the ability to determine the landers' position using radiometric data is inhibited if the lander is unable to communicate directly with the Earth; second we will show a dynamical approach for estimating the orientations of Mars principal inertia axes.

Determining landing coordinates using Phobos eclipse detection corresponds to the inversion of a non-linear, non-continuous and multivalued function that calculates Phobos eclipses contact times as seen from a known observer. Two different algorithms were considered to solve the proposed unconstrained nonlinear least squares problem and different simulations were made to test their feasibility and efficiency under different experimental constraints: Different initial conditions and locations, different uncertainty values for time precision and different number of observed eclipses and landing latitude (Barderas and Romero, 2013). The numerical results show how a lander position could be estimated within an ellipse of 40x60 metres if 1 second uncertainty in time observations were attainable.

Computing the eclipse contact times requires precise information about the size and shape of the involved bodies (Sun and Phobos) and their ephemerides. The developed model and the involved parameters were thus checked with the available observations of Phobos eclipses on Mars of the Mars Orbiter Laser Altimeter and the Mars Exploration Rovers (Harri, A. et al, 2012; Barderas and Romero, 2012b). These testing procedures allowed to choose the values of the parameters which better fit the eclipse observations.

For the establishment of observational strategies for Mars landers with unknown coordinates, the spatial and temporal patterns of the Phobos penumbral footprint on Mars have been also studied. To this end, Phobos shadow centre motion were modelled, as well as its size and shape at any given time (Romero and Barderas et al. 2011). These latter models were applied to determine the eclipses that might be seen from the Mars Science Laboratory (MSL) planned landing ellipse of 25x20 kilometres before its launch (Barderas et al., 2012a). The characterized eclipses were captured by the Mast Camera onboard the MSL, showing the methodology reliability for the establishment of an observational strategy

Finally, in the second part of this work we show how to determine the Solar System Planets principal inertia axes. These orientations are usually derived solving an eigenvalue/eigenvector problem (see Chen and Shen, 2010, for instance for the Earth). Here we present a qualitative analysis made in the embedded space phase that describes the effects of the gravitational perturbations on the longitudinal position at the synchronous orbit (Romero et al 2018).

First, using variational principles, we show that the equilibrium positions in a rotating second degree and order gravity field are located at the synchronous orbit in the equatorial plane and in the directions of the planetary principal inertia axes. Then, from the equations that describe the gravitational perturbations on a longitudinal synchronous position we make a qualitative analysis to locate equilibrium positions that allows to readily place planetary principal inertia axes with respect to planetary conventional prime meridians. We utilise this characterization to determine the orientation of the planetary principal inertia axes for the Solar System inner planets with respect to their Prime Meridians and with respect to the ICRF.

Moreover, we evaluate the non-linear effects on the equilibrium point localization. The differences are explained in terms of the tangential accelerations derived for gravity field harmonic developments of order 2 and 5 at the stationary orbit. We also analyse the correlation of the planetary gravity field with the equilibrium point location. The results show the geographic

locations of the stable points are tied to the greatest gravity anomalies, and the unstable points to the lowest gravity anomalies.

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Nanoparticle based supercapacitors for energy harvesting

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Keywords:
Metamaterial, nanospheres, supercapacitor, EDLC

Abstract:
In this work the potential of a novel technology of supercapacitor based devices is shown. These new devices use different kind of nanospheres to modify the capacitance value and so the energy storage capability. The work focuses on the analysis of the irruption of nanoparticles as they have the intrinsic advantage of the surface to volume ratio, they can be manufactured of many materials, they are widely available and there exists efficient surface functionalizing technology.

There is an increasing need in developing more performant energy storage components for space in terms of specific energy (Wh/kg) or specific power (kW/kg). Supercapacitors are already used in aeronautic industry and the great potential in telecommunication satellites has been recently assessed. In fact, although supercapacitors do not store as much energy as lithium-ion batteries do, they are instead able to deliver higher peaks of energy for short periods of time, which can definitely help the energy management in space instrumentation, covering eclipse periods or electrical load changes.

In Situ Instrument for Mars luminescence dating application

Coccaro, Fabio. Alma-Sistemi, Italy

A precise age determination of the recent events occurred on Mars surface is fundamental to tie-to-time the stratigraphic successions. These successions change through time reflecting changes of processes and/or environments that in turn might depend on climate changes. Understanding the timing of climate change processes is fundamental to infer what controlled their evolution. Until present, relative dating of Mars surface has been studied with the use of crater counting. However, this approach has a very poor temporal resolution and provides a limited contribution to our understanding of the evolution of surface processes. The orientation and geometry of Martian dunes provides interesting information on the direction of sediment transport and thus aeolian processes. Active dune systems have been mostly investigated with the use of space-borne imagery. However, the migration rate appears to be in values too low to be suitable for accurate rate determinations from orbit.

On Earth, luminescence techniques are widely used to study the history of dune systems in order to deduce local and global effect of climate changes. The present study examines the potentiality of luminescence techniques for in-situ dating of modern Martian landscape.

The study describes a miniaturized instrument for in-situ examination and assessment based on luminescence methods. The feasibility of a luminescence-based approach to dating of soil simulants and sediments analogues of Martian deposits is discussed. In order to minimize mass and power consumption, new techniques and procedures that involve no sample heating are under development. Different set of LEDs emitting in visible, infrared and ultraviolet spectral ranges are used to excite different response in different samples' material. A miniaturized X-ray source is used to estimate the correct dosimetry. Martian radiation environment is taken into account with the use of a state-of-the-art radiation model and data from the latest missions.

Through the development of its innovative technology, and on top of its planetary exploration applications, this instrument would also be suitable for terrestrial field applications as a lightweight and portable dating and analysis instrument for geology and archaeology as well as a risk assessment tool for accident and emergency dosimetry and nuclear mass-casualty events.

Experimental characterization of the optical elements of the Dust Sensor (ExoMars '20)

De Castro, Antonio UC3M, Spain

The Dust Sensor (DS) is a low SWaP (Size Weight and Power) factor Planetary Exploration Payload designed to measure the parameters that determine in situ the size distribution of suspended dust on the surface of Mars. This physical information is retrieved from the measurement of scattered infrared (IR) light by the dust particles inside a small volume of interaction (≈3cm3). The Dust Sensor is one of the atmospheric payloads of the METEO instrument that will be launched on the Exomars'20 mission leaded by ESA and Roskosmos.

A computational model of DS has been developed with a twofold purpose. This model has been extensively used to optimize the design of the sensor. On the other hand it is a key tool to develop strategies for the data retrieval analysis by the simulation of a huge number of different particle scenarios. The model includes the source-detectors geometry of the sensor, spectral response of the detectors, the physical equations for the particle scattering calculation, the generation of the particle scenario (size distribution and 3-dimension particle location) or the analogic and digital electronic of the system. Moreover the model has to be feeded with experimental parameters that characterize the optical components: infrared source and infrared detectors. In this work, the experimental procedures to measure these important parameters is presented.

AMR instrument. Scientific objectives and previous measurements on terrestrial analogues

M. Diaz Michelena, INTA, Spain

AMR instrument is part of the scientific payload on board the Surface Platform of the ExoMars 2020 mission.

It is a vector magnetometer whose main objectives are the characterization of the crustal magnetic signature in the landing site and the measurements of the magnetic field daily variations calculating an equivalent k-index.

In order to achieve these objectives AMR instrument has a distributed architecture comprising a former part named E-Box in the surface platform and a second part named S-Box, which will be deployed from the platform (> 2 m).

In this workshop the team will describe the instrument and main capabilities as well as the campaigns in terrestrial analogues previous to the real operation on Mars.

Advanced numerical modeling of thermal sensors for Mars Exploration and working under smart controls

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The objective of this paper is to present three very different alternatives for simulating heat transfer dynamics in thermal sensors, operating under smart controls. The first alternative is the use of high fidelity simulations of heat transfer to fluids by the direct numerical simulation of the Navier-Stokes and energy equations. Results will be presented in the case of a spherical wind sensor for Mars atmosphere. It will be shown that it is possible to analyze the system dynamics in the case of extreme Martian wind velocities, up to the scale of Dust Devils. This approach allows to identify the distinctive patterns to be expected in the experimental results in wind tunnels. A comparison between preliminary experimental results with a sensor prototype and the results predicted by the simulations will be presented.

The other two alternatives are focused on solving heat transfer between solids in the case of heat flux measurements using thermopiles. It is known that commercial FEM tools can be used to analyze 3D temperature and heat flux inhomogeneities in structures. It will be shown that, for certain controls, this allows to analyze what constraints the geometry imposes and how the controls can be used to overcome them. On the other hand, some smart controls make use of high frequency switching in the actuation. The simulation of the physical structure embedded with this type of controls requires then the use of adhoc simulation tools. We will present 1D simulations of heat transfer in thermopiles, in which the Seebeck and Thomson mechanisms have been included, completely embedded with the high frequency actuation generated by the control. With this approach it is possible to obtain the output signals generated by the control from which the heat flux will be estimated. The detailed simulation of the switching allows to understand the complex (and sometimes hidden) dynamics generated by these controls.

Conditions for life to exist: determining environmental parameters on Mars

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Scientists don’t agree on the definition of life. We don’t know what life is. The approach we are presenting in this abstract is the use of Earth Analogues as models for studying life at its extremes. An important question to approach is would it be possible to recognise life if we found it out of Planet Earth?. We need to be trained to being able to recognise any life signal if we find it at the Mars exploration missions. We are presenting here the main characteristics that we use as factors affecting real habitability potential (Habitability Index – HI) and the definition of a mathematical model for HI.

ExoMars 2020 mission objectives and payload

Ari-Mattti Harri

Head of Radar and Space Technology Research
Finnish Meteorological Institute

Confinement of a charged particle in a quadrupolar magnetic field

S. Jiménez[1], D. Usero[2], L. Vázquez[2], M.P. Velasco[1]

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Mars has no planetary dipolar field but some crustal, local magnetic fields persist. Auroras have been observed on Mars, associated to those fields.

Since the studies of Störmer it is known how a dipolar field can trap charged particles, a part of the mechanism that induces auroras. As a second order approach, we study the confinement by a quadrupolar field.

Planetary Atmospheres and Surface simulation chamber: A platform for planetary exploration and astrobiology applications

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Even though space missions provide fundamental and unique knowledge for planetary exploration, they are always costly and extremely time-consuming. Due to the obvious technical and economical limitations for *in-situ* planetary exploration; laboratory simulations are one of the most feasible research options to make advances both in planetary science and in a consistent description of the origin of life. Planetary Atmosphere and Surfaces Chamber (PASC) are able to simulated atmosphere and surface temperature for the majority of the planetary objects and they are especially appropriate to study physico-chemical and biological changes induced in a particular sample due to in-situ irradiation in a controlled environment. Number of relevant applications in planetary exploration will be described in order to provide an understanding about the potential and flexibility of planetary simulation chambers systems: mainly, stability and presence of certain minerals on Mars surface; photochemistry process on molecules and microorganisms potential habitability under planetary environmental conditions would be studied. Furthermore, UV-photocatalytic process on mineral surfaces has shown species potential fixation. Therefore, simulation chambers assess several multidisciplinary and challenging planetary and astrobiological studies. Furthermore, will be a promising tools and necessary platform to design future planetary space mission and to validate in-situ measurements from orbital or rover observations.

Aspects of the IN-TIME Project: Martian Atmosphere

Lara Quitián Hernández[1], Francisco Valero Rodríguez[1]
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The growing and unceasing interest in the Martian exploration along with the advances in the improvement of the terrestrial meteorological models of limited area, has propitiated the ideal scenario in order to obtain the perfect adjustment of these models to the Mars atmosphere.

The use of these models has become an essential tool when evaluating the risks in the stages of entry, descent and landing. Similarly, they allow us to better understand the so complex and interesting atmospheric processes that occur in the Martian atmosphere and their effects on the operation of every lander's instrument.

The IN-TIME project, designed as a multidisciplinary program in which different areas of knowledge such as Geoscience, Physics, and Engineering are combined, aims to develop a leading-edge instrument based on the luminescence method able to carry out in-situ datation of diverse Martian surface samples. Thanks to its portable and light manufacturing, this instrument will also be useful in terrestrial applications. However, none of these in-situ measurements can be carried out if all meteorological processes that could occur at such location are not previously well-controlled. Therefore, it is intended to define and develop a local numerical model capable of reproducing different meteorological processes, characterizing the possible effects of radiation on the Mars surface and atmosphere.

MEDA, the instrument onboard Mars2020 to characterize the dust cycle and the environment near the surface

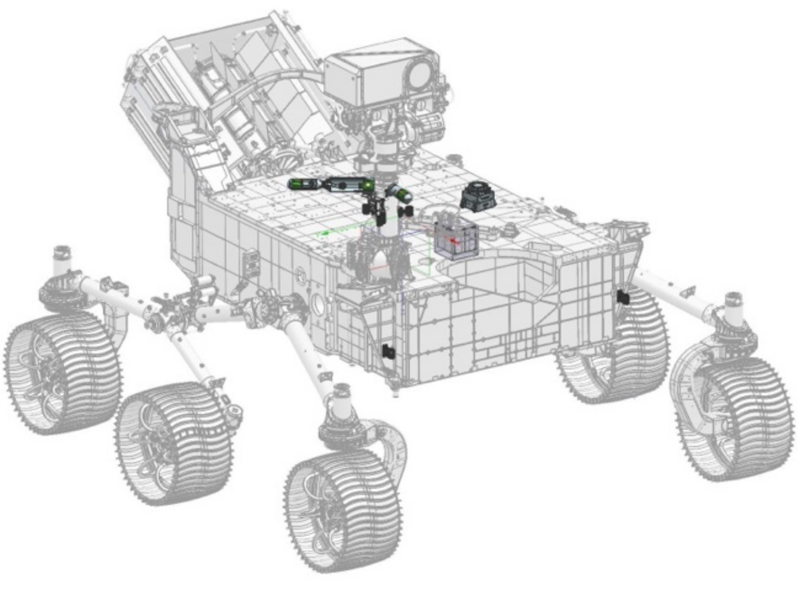
J.A. Rodriguez-Manfredi and the whole **MEDA team.**
CAB, Spain

The NASA's Mars2020 rover includes a suite of sensors to characterize the atmospheric dust aerosols cycle, as well as the local environment near the surface: the *Mars Environmental Dynamics Analyzer* (MEDA) instrument.

The Mars2020 mission is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the red planet. Designed to advance high-priority science goals for Mars exploration, the mission would address key questions about the potential for life on Mars. The mission would also provide opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions to Mars.

Within this context, MEDA's sensors will characterize the climate near the Martian surface. Those sensors are a dust and optical radiation sensor (RDS) that includes a dedicated camera (SkyCam), pressure sensor (PS), relative humidity sensor (HS), wind sensor (WS), 5 air temperature sensors (ATS), and a thermal infrared sensor (TIRS) for net flux and ground temperature.

The solar radiation sensors will track direct and diffuse radiation in a geometry that characterizes the prevailing environmental dust properties, the behavior of solar radiation on subdiurnal time scales, and the impact of solar radiation on local photochemistry, thus supporting assessments of the preservation potential for organics on a cache sample. The other sensors will enable comparisons to the environments found at other locations explored by environmental packages aboard previous landers and rovers on Mars. The MSL REMS heritage additionally permits easy comparisons to the meteorological station currently operating on Gale Crater.



MEDA assemblies distributed over the Mars 2020 rover (Picture courtesy of NASA-JPL/Caltech)

Thus, MEDA’s measurement objectives are:

a. The physical and optical properties of the local atmospheric aerosols. Particle abundance, size distribution, shape, phase function, and how these optical properties relate to the meteorological cycles (diurnal, seasonal, interannual).

b. The conditions leading to dust lifting and how the aerosol diurnal cycle responds to the local atmospheric wind regimes.

c. How the current environmental pressure, temperature, relative humidity, solar radiation, net infra-red radiation, and winds at the landing site differ from those at the Viking, Phoenix, Pathfinder, and Curiosity locations.

d. The relationship between the surface environment and the large-scale dynamics observed from orbiting instruments.

e. The energy and water fluxes between the sur-face and the lower atmosphere of Mars near the rover.

f. The annual cycles of the solar UV, visible and NIR radiation on the surface of Mars.

g. The environmental context for weathering and preservation potential of a possible cache sample.

h. How pressure, humidity, temperature and winds influence the ISRU engineering efficiency.

i. How the MEDA observations agree with models extrapolations to the Martian surface.

We will describe the fundamentals and performances of the different sensors that have been built over the last 4 years, and recently delivered to JPL/NASA to be installed on the next NASA’s Martian explorer.

MINIMUM-THRUST OPTIMIZATION IN THE MISSION DESIGN OF AEROSTATIONARY TELECOMMUNICATIONS ORBITERS

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Abstract:

Small relay satellites in areostationary orbit are considered the most efficient candidates to support the telecommunications needs of Mars exploration in the 2020s. Areostationary orbiters can provide continuous access at very high data rates to remotely supervise a significant population of probes and robotic missions on the Martian surface.

The determination of optimal transfer trajectories Earth to Mars aiming to lower costs in terms of impulses has become a key factor in mission planning, allowing for more massive payloads to be transported by Solar Electric Propulsion at a minimum energy cost.On the other hand, optimal correction strategies need to be implemented to minimize the thrust consumption for compensating the natural perturbations that tend to shift an areostationary satellite from its nominal station point.

In this work we first focus on the determination of optimal interplanetary trajectories from Earth to Mars by minimizing the total required impulses magnitudes in the major mission phases: Earth departure, interplanetary targeting orbit and Mars arrival. Such analysis is done by solving the Lambert orbital boundary-value problem and investigating the optimal departure and arrival windows. The first step consists in finding the positions and velocities of the departure from Earth and the arrival to Mars by solving the Lambert problem for various combinations of departure and arrival dates. Then, departure characteristic energy and hyperbolic arrival velocity plots are independently examined to investigate possible transfer orbits. After this preliminary analysis, an optimization procedure is applied to simultaneously minimize these two key parameters comparing the performance of several genetic algorithms. Finally, the optimal heliocentric transfer trajectory orbital elements are determined. The results of the analysis lead to an optimal choice of departure and arrival dates that minimize the necessary amount of needed impulses for an Earth to Mars mission.

Once solved the optimal hyperbolic arrival trajectory about Mars, optimal necessary maneuvers in order to capture the orbiter and to and place it the areostationary orbit are analyzed.

Finally, the effects of the dominant disturbing forces on the aerostationary orbit due to the Mars gravitational field, the gravitational attraction of the Sun and the Martian moons, Phobos and Deimos, and solar radiation pressure are modelled, and optimal Station-Keeping maneuvers to control the evolution of areostationary satellites are evaluated.

Acknowledgements: This work has been funded by grants: ESP2016-79135-R by the Government of Spain, S2013/ICE-2845 (CASI-CAM) by the Government of Madrid, EC H2020-MSCA-RISE-2015 691161 GEO-SAFE.

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LIR-UC3M infrared sensors for Mars Atmospheric Science retrieval

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Infrared Laboratory of the Universidad Carlos III of Madrid is transferring their technological knowledge to the Space Instrumentation. The past, present and future of this contribution to Mars Atmospheric Science will be presented. On this regard, the group has been developing the Dust Sensor based in Infrared technology for different science missions as: MEIGA-MetNet payload for the Mars MetNet Mission and for Radiation and Dust Monitor (RDM) for METEO payload for ExoMars mission. The future of the Dust Sensor and further Space developments form the Laboratory will be addressed.

Present and future of atmospheric numerical modelling

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There are different ways to model the atmospheric behavior. During the last years, due to the increase of computational power and the demands of more detailed meteorological information, most of these techniques have a closer interaction. The collaboration between diverse communities and techniques, such as parallel programing, big data, artificial intelligence, are creating a new playground for meteorologists and computational scientists.

Traditionally, the short-range operational weather forecasting has been based on numerical limited area models. In Europe, these models have mostly being developed by consortia of collaborating National Meteorological Services. HIRLAM (High Resolution Limited Area Model) was the first of these consortia on limited area modelling in Europe, established in 1985.

In 2005, the strategic decision was made for HIRLAM to engage in a close code cooperation with the ALADIN consortium. The aim of this research collaboration is to develop and maintain a common, state-of-the-art mesoscale LAM model code for short-range numerical weather prediction, within the code framework of the ECMWF/Arpege Integrated Forecasting System (IFS).

The collaboration in HIRLAM is organized in the form of five year programmes. The current one, HIRLAM-C (2016-2020), has in between its objectives, to work together with ALADIN with the aim of forming a 26 countries single consortium at latest by the end of 2020.

The current HIRLAM, and the new consortia after 2020, will continue exploring new techniques and methods to increase the forecasting capabilities for the met services all over Europe.

IN-TIME project: Overview and Definition of the Mars Radiation Environment

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Obtaining an accurate estimation of absolute ages of Martian sediments is necessary to understand the geological processes and Mars climate evolution. An effort to improve the geochronology of Mars will be done in the framework of the IN-TIME European project. In order to date Mars surface and sub-surface sediments, IN-TIME aims to build a luminescence-based instrument, which is intended to become part of future missions rovers' payload. In addition, a miniaturized version of the instrument will be developed as an application to be used on Earth in disciplines such as archaeology, geology or risk assesment for emergency events where dosimetry is required.

Luminescence dating relies on defects in the crystal lattice of dosimeter minerals, in order to trap energy produced during the interaction between electrons within the crystal. Therefore, an accurate characterization of the background radiation from radionuclide radioactive decay and galactic cosmic rays is really crucial to properly use this technique. Consequently, the definition of the Mars radiation environment needs to be addressed.

Some previous studies have dealt with this topic using measurements from earlier missions. On the other hand, a few Martian radiation models have been developed, focusing on the fact that measuring the radiation on the surface of Mars is essential prior to human exploration. Here an overview of the IN-TIME project is presented, focusing on one of its initially critical topics: the characterization of the Mars radiation environment.

DIELECTRIC RESONANT MAGNETIC DIPOLES: PARADOXES, PROSPECTS, FIRST EXPERIMENTS

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The theoretical basis and experimental verification of resonant phenomena in the electromagnetic fields generated by displacement currents in the near zones of thin all - dielectric circuits of circular and elliptical shapes are presented. Interaction of driving microwave with the non – conducting circuit gives the rise to excitement of displacement and polarization currents in these circuits. Formation of resonant dielectric magnetic dipoles due to the grazing incidence of microwave is shown and inversion of magnetic inductance providing the appearance of media with negative magnetic permeability is demonstrated. The components of scattered wave field are characterized by sharp and deep resonances. Resonant interaction spectra of a pair of magnetic dipoles with finite sizes is discussed. Control of microwaves flow by means of gradient dielectric structures is shown. Perspectives of using of sub wavelength and low loss magnetic dipoles in the all-dielectric circuitry as well as for modeling of optical nanostructures are considered.

Aeolian features on Mars

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The surface of Mars is spanned by strong winds that accumulate at the surface vast fields of bedforms (dunes and ripples). Some of them are active while others seem to be relict of a past climate. Bedform morphology and dynamic can thus be used constrain present and past climatic conditions on Mars. Image from orbiters (MRO, ExoMars and TGO) can be used to monitor the dynamic of these features giving precious hints on present winds and providing invaluable ground-truth for atmospheric models. In addition, monitoring the activity of aeolian bedforms in landing sites can be fundamental for validating in situ meteorological measurements. In this presentation, I will focus on active and relict aeolian features on Mars with particular emphasis on ExoMars (2016 and 2020) and MSL.

The UCM Martian Studies Group: History and Achievements

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We describe some data of the Martian research activity in the framework of the Martian studies at Complutense University. In this context of enthusiasm for the space exploration, we have to locate some of the activities of the Martian Research Environment at Complutense University from 2007 (*https://plataforma-aeroespacial.es/pae/miembros/universidades/ http://www.foroempresasinnovadoras.com/*). Inside the Complutense University different Faculties and Departments are involved. At the same time, we have to consider the participation of other universities: Universidad Autónoma de Madrid, Universidad Politécnica de Madrid and Universidad Pontificia Comillas.

The singular event to push and to launch the Martian research at Complutense University was the creation of the Astrobiology Center associated to NASA (http://www.cab.inta-csic.es/es/inicio) in 1998. Francisco Anguita and Luis Vázquez were cofounders of such a centre. In this context, Luis Vázquez started to be involved in the Missions to Mars. The first participation was in the period 2001-2003: Beagle 2 (Mars Express, ESA), by coordinating the calibration of the Ultraviolet sensors. In the period 2004-2007, Luis Vázquez participated as PI and Francisco Valero as Co-I of REMS-Curiosity (NASA): http://mars.jpl.nasa.gov/msl.

The Mission which structured the Martian Research Environment at Complutense University was the joint project METNET (Meteorological Network) of Spain (INTA, UCM, UC3M and Instituto de Microelectrónica de Sevilla) with Finland and Russia (2007-2015). The goal of this project is to send to Mars a network of meteorological stations (http://www.meiga-metnet.org, http://metnet.fmi.fi/index.php?id=72).

Martian research achievements in the period 2007-2015 (Boletin Electrónico SEMA n.14 (2017) 3-15)

The research activity is carried out mainly in three thematic blocks described as follows:

1. Martian planetary boundary layer, magnetic field and radiation

– To compare Mars and Earth planetary boundary layers (PBL) and the associated surface layers. The different scale processes.
– To compare the Turbulent Kinetic Energy (TKE) budgets in Mars and Earth.
– Aspects of the PBL that require new measurements in order to constrain models.
– Dynamics of the Martian dust. Electric fields.
– Modelling local Martian magnetic fields.
– Solar radiation on the Martian surface.
– Atmospheric effects on the remote determination of thermal inertia on Mars.

2. *Data mining and modelling*

– Cloud Computing.
– Fractional Calculus: Suitable mathematical tool to model nonlocal phenomena either in time and/or in space:

– Tomographic methods and structural equations to identify events very localized either in time and / or space as the dust devils, auroras,etc
– Determine future trends of the geomagnetic field changes: detection of geomagnetic anomalies, identify different magnetic events related to the solar activity.
– At present we are involved in the electric and dust analysis (group of Francesca Esposito).

3. *Geodesic studies: modelling the Phobos eclipses*
– To detect the Phobos eclipses
– Determination of rover/lander position using Phobos transits
– Implications for the Phobos orbit from its shadow information.
– To improve the estimate of tidal dissipation within from shadow of Phobos observations.

4. *Ph.D.studies in the Martian Research Environment associated to the project Meiga-MetNet*
The students are the vectors of the future and especially in the framework of the Space Science and Technology. For this reason, the MRE associated to the Project Meiga-MetNet dedicates special attention to the training and outreach at different levels (summer schools at El Escorial, conferences in high schools, international meetings, and interchanges with international space centres). Special achievements are the eight completed thesis under the umbrella of the Martian space research.

5. *Present status (2016-)*
In this new period, we are supported by the Ministerio de Economía y Competitividad under the grant ESP2016-79135-R. On the other hand, the instruments previously developed in the framework of METNET are included in the missions ExoMars2016 and ExoMars2020.We are very involved in the Mission Mars Express, more precisely in the study of the data from Marsis. On the other hand, we also participate in ExoMars2016 and ExoMars2020. In the first case, we participated as Co-Is in the payload package DREAMS (Dust Characterization, Risk Assessment and Environment Analyser in the Martian Surface) of the lander Schiaparelli, and in the Atmospheric Chemistry Suite (ACS) of the orbiter TGO (Trace Gas Orbiter). In this period, our activity could be summarized as follows:
– Continuation of the study of REMS-Curiosity data: Pressure, Humidity, Temperature, Ultraviolet Radiation.
– Preparation of the structure and protocols of cloud computing to be used with the ACS data.
– Study of the eclipses of Phobos for the missions ExoMars2016 and ExoMars2020. Optimization of parameters. Communications.
– Study of data set with non-uniform acquisition.
– To complete the development of the tomographic method to detect events very localized either in space and / or time.
– Application of the Fractional Calculus to model non local phenomena either in space and/or time.
– Applications to the analysis of biological signals.
– Applications to the study of economic data in collaboration with Instituto de Investigaciones Económicas y Sociales “Francisco de Vitoria”.
--Participation in the European Project IN TIME for Mars exploration. The goal is to prepare a device to date the rocks based on the luminescence.

A final remark: A mission can fail but what cannot fail is the associated environment research. On the other hand, the Space Research Environment is a strategic issue for the University since it is interdisciplinary, transdisciplinary, global and international, at the same time that has provided a natural link with the industry.

Computing Solutions for Mars Exploration: from the Cloud to Serverless

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1. Introduction

Mars Exploration is a challenging for different aspects related to data process and storage. During the past years, the Mars Studies Group at Universidad Complutense de Madrid has been relying on distributed computing, in order to provide valid solutions to different Space missions by means of performance and cost.

2. Cloud and serverless computing

Cloud computing is a provision paradigm that allows the dynamic, flexible and elastic supply of computing resources. These computing resources can be expressed by means of processing nodes or data repositories, and there are providers that offer these services for a fee. These so called public cloud providers are an interesting way to reduce operating costs, such as machine purchase and maintenance.

Serverless computing is an execution model offered by cloud, where a code is provided by the user to be run without any involvement in server management. Costs are even more reduced with serverless as there is no need to install and maintain operating systems or licenses. Even if it is impossible to persistently store data, unless an external method is defined, complexity inherent to multitasking and request handling is almost reduced.

3. Computing solutions

Work on cloud solutions have been done by the group since its participation in the Mars MetNet mission while studying Phobos' eclipses [1], [2]. The results of this initial work were then applied in NASA's Mars Science Laboratory [3].

Cloud computing was also used in the group's study of the Martian atmospheric dust dynamics [4] in the context of the ESA ExoMars 2016 mission.

It was with the participation in the ESA Mars EXpress mission when the group started to work on serverless computing solutions. In this case, efficient processing was delivered for the MARSIS instrument data [5].

Finally, this distributed computing know-how was applied to the exploration of other Solar System planets. This was the case of the Venus Express VMC image processing, where a strategy mixing public and private cloud infrastructures was introduced [6].

During the talk these computing solutions will be showcased, along with the foundations of the involved technologies.

Acknowledgments

The authors would like to thank the support provided by the European Commission under the IN-TIME project (Grant 823934).

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Dynamic of the Martian atmospheric dust through fractional diffusion models

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The dust aerosols have an important effect on the solar radiation in the Martian atmosphere and both surface and atmospheric heating rates, which are also basic drivers of atmospheric dynamics.

Aerosols cause an attenuation of the solar radiation traversing the atmosphere and this attenuation is modeled by the Lambert-Beer-Bouguer law, where the aerosol optical thickness plays an important role. Through Angstrom law, the aerosol optical thickness can be approximated as a second order moment and then this law allows to model attenuation of the solar radiation traversing the atmosphere by a fractional diffusion equation.

The analytical solution of the fractional diffusion equation is available in the case of one space dimension and three space dimensions with radial symmetry. When we extend the fractional diffusion equation to the case of two or more space variables, we need large and massive computations to approach the solutions through numerical schemes. In this case a suitable strategy is to use the cloud computing to carry out the simulations.

In this study, we discuss some questions of the model and experimental data. We present analytic solutions for this modeling problem in one and three space dimensions and numerical methods that allow us to obtain computational simulations of the solutions. Also, the fractional model provides information that can be understood in term of higher order moments and this relation establishes a meeting point and discussion regarding to the experiments. In this context, we are working in the fitting of the fractional model to dust observational data.

Some information about San Lorenzo de El Escorial

citing wikipedia (edited):

«The **Monasterio de el Escorial** is a historical residence of the King of Spain, in the town of San Lorenzo de El Escorial, northwest of the Spanish capital, Madrid. It is one of the Spanish royal sites and has functioned as a monastery, basilica, royal palace, pantheon, library, museum, university, school and hospital.»

Some webs of interest:

Tourist information in several languages including:

Spanish: http://sanlorenzoturismo.es/	**English:** http://sanlorenzoturismo.es/en	**Russian:** http://sanlorenzoturismo.es/ru

The Monastery:	
The monastery (English)	***The monastery (Spanish)***
https://www.patrimonionacional.es/en/real-sitio/real-sitio-de-san-lorenzo-de-el-escorial (English)	https://www.patrimonionacional.es/real-sitio/real-sitio-de-san-lorenzo-de-el-escorial (Spanish)

The Auditorium:	***The Coliseum (1771):***
https://www.teatroauditorioescorial.es/	http://www.comunidad.madrid/centros/real-coliseo-carlos-iii-san-lorenzo-escorial

(sorry: only available in Spanish)

Our hotel: Los Lanceros

https://www.loslanceros.com/ (Spanish)	https://en.loslanceros.com/ (English)	https://ru.loslanceros.com/ (Russian)